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IOP Conf. Series: Materials Science and Engineering **631** (2019) 042044 doi:10.1088/1757-899X/631/4/042044

Research on Reactive Power Adjustment Capability of Hydro-generators

Dawei Jiang[1], Xinyu Qian[2*], Longbin Yu[1], Guanyu Wang[1], Zijian Zhao[1], Xiang Cheng[2], Jing Li[2]

[1]Electric Power Research Institute of State Grid Liaoning Electric Power Co., Ltd, Shengyang, Liaoning, 110006, China

[2]Electric and Engineering Department, Shenyang University of Technology, Shengyang, Liaoning, 110870, China

[*]Corresponding author's e-mail: 2557205746@qq.com

Abstract. With the continuous access of new energy sources to the power grid, the requirements of the power grid for reactive power adjustment capability are also continuously improving, and stronger reactive power adjustment capability is needed to keep the power grid voltage in a controllable range.To maintain the terminal voltage level of the generator, improve the operation stability of the power system, a superior excitation control mode is proposed in this paper. The open loop control and PID control under full load and partial load conditions are compared. The conclusions have some reference value for the study of reactive power adjustment capability of hydro-generators.

1. Introduction

The generation and application of electric energy promote the development of human society and human civilization.However, water is clean and renewable energy. Foreign countries usually give priority to the development of hydroelectric power, water resources rich countries, the proportion of hydroelectric power is also high. Such as: Sweden, Switzerland, France, Italy and other countries were in the proportion of water and electricity in 60% to 70%, Norway's water and electricity proportion even reached 98.9%[1]-[2]. Mature hydroelectric power technology is widely used for its merits of stable output, high reliability, good economy and obvious advantages of flexibility which makes the power grid operation is stable. But in actual operation, the load of the power system is constantly changing, for example, the electricity consumption in winter is higher than that in other seasons. Therefore, it is necessary to adjust the generating capacity of each power plant to maintain the balance between supply and demand of electric energy. Therefore, it is imperative to control the voltage stability to maintain the normal operation of the generator set and the safety and stability of the power grid. Excitation control also plays a very important role in how to maintain the safety and stability of power system. Therefore, among many methods to improve the stable operation of generators, optimizing the control mode of excitation system is one of the economic and effective methods[3]-[4]. Therefore a superior excitation control mode is proposed in this paper. The open loop control and PID control under full load and partial load conditions are compared. The conclusions have some reference value for the study of reactive power adjustment capability of hydro-generators.

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2. Influence of Basic Regulation on Power System Stability

2.1. Influence on Static Stability

Static stability of power system means that after receiving small interference signals, excitation system can maintain constant voltage at designated points of power system, and its power angle characteristics are:

$$P_m = \frac{E_q * U_s}{X_g} \sin\delta \tag{1}$$

Where E_q is that potential in the generator; U_s is the grid voltage at the machine end; X_g is the total reactance between generator and power grid; δ is the angle between the terminal voltage of the generator and the internal potential of the generator.

In the absence of excitation system, E_q is a constant, corresponding to

$$P_m = \frac{E_q * U_s}{X_g} \tag{2}$$

After adding excitation system, E_q is a variable, which corresponds to

$$P'_m = \frac{E'_q * U_s}{X_g + X_d} \tag{3}$$

Where E'_q is generator transient potential, X_d is generator transient reactance. The specifications of generator and line parameters (nominal value) are shown in table 1.

Table 1.Generator and line parameters (per unit) table.

Generator and line parameters	X_d	X_q	X_{t1}	X_{t2}	X'_d	X_e
Standard value parameter	1.5	1.5	0.1	0.1	0.3	0.8

Among them, X_q is the quadrature axis reactance of motor, X_{t1} is the impedance of transformer T_1, X_{t2} is the impedance of transformer T_2, X'_d is the secondary transient reactance of the motor, X_e is the impedance of the line.When there is no excitation mediation, the transmission power is:

$$P = \frac{E_q * U_s}{X_d + X_{t1} + X_{t2} + X_e} \sin\delta \tag{4}$$

When δ = 90°, the generator has the maximum transmission power:

$$P_{\max} = \frac{E_q * U_s}{X_d + X_{t1} + X_{t2} + X_e} \tag{5}$$

When there is excitation mediation, the transmission power is:

$$P = \frac{E'_q * U_s}{X_d + X_{t1} + X_{t2} + X_e} \sin\delta' \tag{6}$$

When δ' = 90°, the generator has the maximum transmission power:

$$P'_{\max} = \frac{E'_q * U_s}{X_d + X_{t1} + X_{t2} + X_e} \tag{7}$$

Bring parameters into availability:

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$$P_{\max} = 0.4$$
$$P'_{\max} = 0.77 \tag{8}$$

2.2. *Influence on Transient Stability*

Transient stability of power system means that after receiving large disturbance signal, excitation system can be adjusted, and then generator can return to original operation state by itself. All kinds of large disturbances can be summarized as single-phase short-circuit grounding, two-phase short-circuit fault and system short-circuit. Equation (9) can be used to describe the change of power characteristics under short circuit fault:

$$P_{\mathrm{m}} = \frac{E_q * U_s}{X_d + X_{t1} + X_{t2} + \frac{X_e}{2}} \tag{9}$$

At present, there are mainly two methods to improve the transient stability, one is to improve the fault removal time; the other is to force the increase. The excitation multiple causes the potential E_q in the generator to rise rapidly, increasing the power output.

3. Hydraulic Generator Model and Its Parameter Setting

3.1. *Influence on Transient Stability*

The hydro-generator is a synchronous motor, so the synchronous motor model is selected. And the standard unit value is used to facilitate the simulation of excitation control system, so PU units is selected as the research object, and its model is shown in Figure 1.

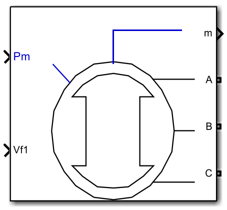

Figure 1. Synchronous generator model

Hydro-generator Model: Standard-value Salient Pole Synchronous Generator Synchronous Machine Pu Standard.Using a 7.5kW/380V/50Hz motor model, the direct-axis reactance X_d is 1.305, the direct-axis transient reactance X'_d is 0.296, the corresponding torque T'_d is 4.49, the direct-axis sub-transient reactance X''_d is 0.252, the corresponding torque T''_d is 0.0681, the cross-axis reactance X_q is 0.474, the cross-axis sub-transient reactance X''_q is 0.243, and the corresponding torque is T''_q 0.0513, the leakage reactance X_1 is 0.18, the stator resistance R_s is 0.01.

3.2. *Regulation Effect under Conventional PID Excitation Control Mode*

Referring to PID controller in Simulink library a conventional simulation model is established in this paper. At the same time, an open-loop simulation model of the system is established to simulate the situation of pure manual control. The model is shown in Figure 2. When the switch is above, it is open-loop control and when the switch is below, it is conventional PID control.

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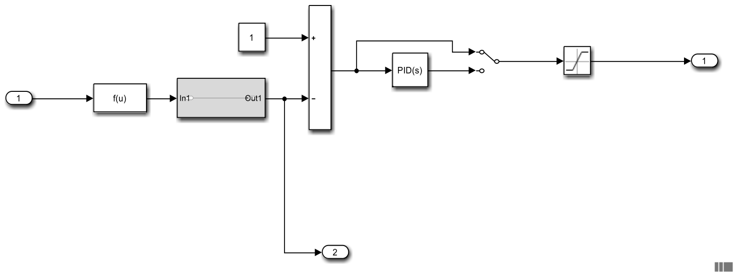

Figure 2. General PID control and open-loop control simulation model

Encapsulating Figure 2, a system simulation model is established. The simulation of full load and partial load is realized by using three-phase circuit breaker. As shown in Figure 3.

The active power consumed by one load is 1×10^3, the active power consumed by the other load is 6.5×10^3, and the inductive reactive power consumed is 1×10^3.

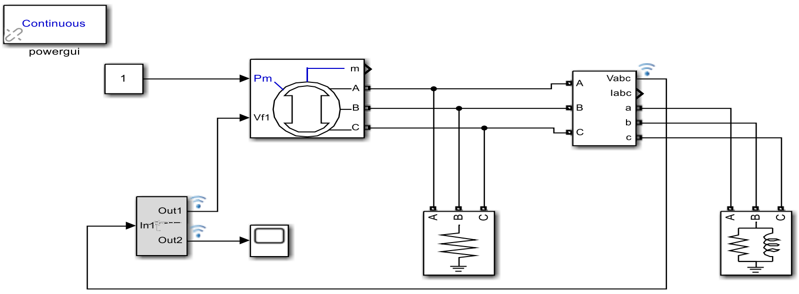

Figure 3. Simulation model of conventional PID control excitation system

a. Open-loop control

The switch of conventional PID regulation and open-loop regulation simulation model in Figure 2 is closed to the upper end to realize the open-loop of the system adjustment.

(1) When full load runs, two loads are connected. The simulation results are in Figure 4.

(2) When part of the load is running, only one load is accessed. The simulation results are in Figure 5.

Through the simulation of the open-loop system, it is found that when the motor is running at full load, it will affect the stability of the power system to some extent and threaten the stability of the system.

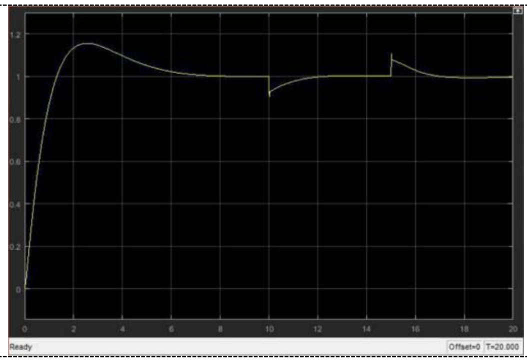

Figure 4. Open loop control full load simulation results

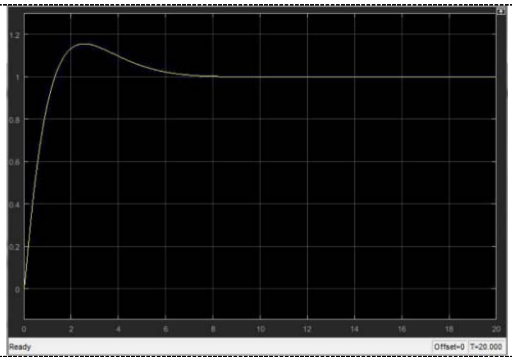

Figure 5. Open-loop control part load simulation operation results

b. Conventional PID control

The switch of conventional PID regulation and open-loop regulation simulation model in Figure 2 is closed to the bottom end to realize the open-loop of the system adjustment.

(1) When full load runs,two loads are connected.The simulation results are shown in Figure 6.

(2) When part of the load is running, only one load is accessed. The simulation results are shown in Figure 7.

Compared with open-loop control, the adjustment time and rise time under PID control are obviously lower than those under open-loop control. The peak value is lower than that of open-loop control, and the overshoot is also reduced. Obviously, the system under PID control is more stable, and the recovery after disturbance is faster.

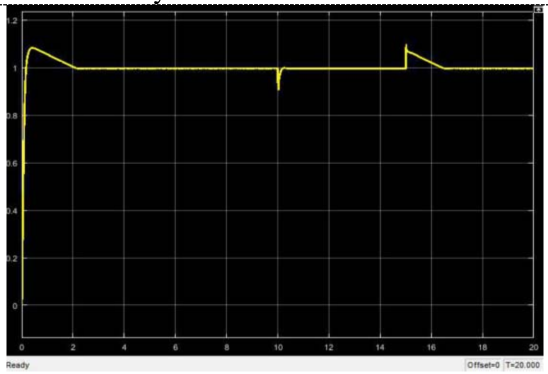

Figure 6. Result of the full-load simulation running of a conventional PID control

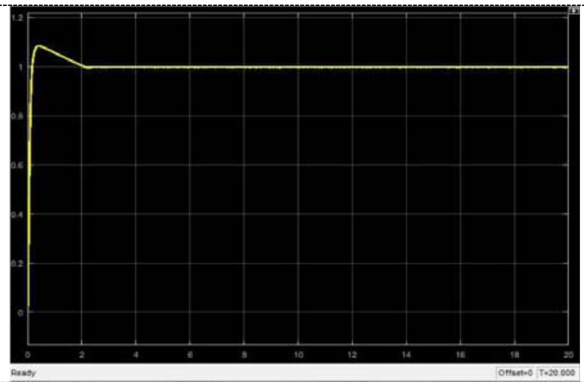

Figure 7. Results of a Partial Load Simulation Operation of a Conventional PID Control

4. Conclusions

The mathematical models of hydro-generator and excitation system are established and different operating conditions are simulated respectively-partial load operation and full load operation. Based on Simulink simulation platform in MATLAB, PID control is also studied in this paper. Based on the models, the following conclusions can be got.

1. The system will be disturbed when it is fully loaded.
2. Open-loop control is far worse than PID control in terms of maximum peak value, adjustment time, rise time and maximum overshoot. Therefore, it is particularly important to adopt necessary adjustment methods in the system.
3. Excitation system is an important component of hydro-generator unit, which can maintain the voltage level of terminal voltage or specified point, maintain the static and transient stability of power system, and reasonably distribute reactive power.

Acknowledgments

This work was from the project named research on reactive power adjustment capability of hydro-generators, supported by Electric Power Research Institute of State Grid Liaoning Electric Power Co., Ltd.

References

[1] Qiao G, Li W, Li F, Shen X. (2010) Development of Parameter Identification and Verification Tool for Synchronous Generator Excitation System. J. Electrical Engineering, 34(11):1348-1353.

[2] Yao W, Wen J, Cheng S, Jiang L. (2012) Development of power system simulation toolbox based on MATLAB/Simulink. Power Grid Technology, 36(06):95-101.

[3] Xiong W, Qin X. Research on Generator Stability Control in Power System Based on MATLAB. (2015) Computer and Digital Engineering, 43(05):831-835.

[4] Zhang W, Chen L, Yu L, Liu Y. (2014) Simulation Research on PSS and Excitation System of Synchronous Generator. Journal of Nanjing University of Information Engineering (Natural Science Edition), 6(03):221-225.